Assessing Sensitivity to Eutrophication of the Southern Puget Sound Basin: Spatial and Seasonal Perspectives

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The southern basin of Puget Sound (south of the Tacoma Narrows) is characterized by slow circulation and shallow bathymetry, relative to other major Puget Sound basins. Human population growth in the adjoining watershed areas is projected to grow steadily, bringing increasing development, deforestation, and shoreline impacts. Washington State Department of Ecology/Puget Sound Ambient Monitoring Program Marine Waters Monitoring data show that a high percentage of monitoring stations in South Puget Sound exhibit characteristics indicating sensitivity to eutrophication. Despite relevancy to planning, there is very little information about the nutrient, oxygen, and phytoplankton dynamics in South Puget Sound. We are currently involved in two studies addressing this issue: 1) SPASM, Southern Puget Sound Area Synthesis Model, utilizing computer models of hydrodynamics and water quality, and 2) CISNet, Coastal Intensive Site Network, developing an *in-situ* profiling mooring (ORCA, Ocean Remote Chemical Analyzer). In support of both of these studies, we conducted a series of intensive cruises during 1997-2000 to measure basic water properties such as nutrient, dissolved oxygen, and chlorophyll levels at 80 stations within South Sound. We present spatial and seasonal patterns of variation in these properties with identification of the areas potentially sensitive to eutrophication. Sections displaying contoured values of salinity, temperature, nutrient, dissolved oxygen, and chlorophyll levels show areas, such as Budd, Carr and Case Inlets, where stratification persists and where low dissolved oxygen concentrations develop. In addition to these observations, we tested whether primary production was nutrient-limited at five of these stations each cruise. While all stations show some degree of nutrient-sensitivity, this condition was especially pronounced in Carr Inlet. The data collected from these cruises show that concerns about water quality impacts from growth-related eutrophication in South Sound are well-founded and should be taken into consideration in planning.

Dairy Waste Impacts on Tribal Shellfish: The Cow-to-Clam Connection

Michael Cochrane
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This presentation will present results of fecal coliform monitoring of the Nooksack River watershed in Whatcom County Washington over the last three years. Also described will be the development of a watershed wide monitoring plan, point and nonpoint source identification, and fecal coliform transportation dynamics.

The problem is chronic and mostly a problem of adjacent regulatory standards. It takes a fecal coliform count of over 200 to violate Class A water quality standards at the mouth of the Nooksack River. It only takes a fecal coliform count of 44 to violate Shellfish growing water standards three miles downstream.

The current fecal coliform standard was designed to be an indicator of human health risk from human viruses coming from human sewage. Cows don't get human viruses. So, in this case, we have an indicator of human health risk being applied to a non-human source.

This presentation will be of special interest to those curious about the role a Federally recognized Treaty Tribe can play in focusing attention and resources on water quality issues.

Oceanographic Survey of Commencement Bay, Washington—Spring 2000

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Oceanographic measurements of Commencement Bay, Washington, made in the spring of 2000 will be presented. CTD/Rossette casts were made to near bottom depths across the mouth of the bay, across the Tacoma tide flats waterway entrances, and at points leading into Colvos Passage and the Tacoma Narrows. Vertical plankton tows to 30 m were also collected at select stations. Our investigations focused on current, plankton, nutrient, temperature and salinity data, which are displayed and compared with historical data. In addition, historic current data within the bay are displayed in animated format by converting data points from a multi-depth 1980 drogue study into animated form, using modern GIS software unavailable at the time of the original study.

Seasonal Cycle of Deep Water Properties in Puget Sound: Their Interannual Variability and Sensitivity to Climatic Factors

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Historical and contemporary deep hydrographic measurements in the Main Basin of Puget Sound are analyzed in order to characterize the canonical seasonal cycle of deep water properties and their interannual variability. A well-defined seasonal cycle is found. Temperature peaks in late August to early September with an average maximum value of 12.5 C and bottoms in February with an average minimum of 8 C. Salinity maximum is typically reached in October with an average value of 30.7 PSU, and the minimum between February and May with an average of 29.5 PSU. Salinity shows significant year-to-year variability. The minimum value of salinity, for example, varies by as much as 0.7 PSU, which is 60 percent of the average range of the seasonal cycle, and the timing of the minimum also varies, in some years occurring as late as in June. In contrast, the maximum salinity remains remarkably stable from year to year, except it may fall below 30 PSU in years in which coastal upwelling in the Pacific coast is reduced due to the influence of El Nino - Southern Oscillation. Correlation of deep water properties with other major climatic parameters, and sensitivity of Puget Sound circulation to changes in forcing, will be discussed.

Spatial and Temporal Variations of Conventional Water Quality Parameters in Marine Waters of the Central Puget Sound Basin

Scott Mickelson
King County Department of Natural Resources

Population growth in King County has necessitated planning a new wastewater treatment plant with a Puget Sound outfall. King County is conducting a marine outfall siting study (MOSS) as part of the planning process. A study of conventional water quality parameters in central Puget Sound was undertaken to characterize spatial and temporal variations of these parameters.

The two-year study began in December 1998 with CTD transects at seven locations in the central Puget Sound Basin and Possession Sound. Marine water samples have also been collected monthly from twelve sites since February 1999. Water quality parameters have been measured using a combination of *in situ* sensors and laboratory analyses and include nutrients, chlorophyll, dissolved oxygen, salinity, temperature, turbidity, solids, density, and optical properties.

Preliminary analysis of the data indicates classic patterns of temporal variation in conventional water quality parameters due to seasonal nutrient uptake and primary production. The data also indicate spatial variation between sampling locations such as a seasonal depression of dissolved oxygen in Possession Sound. Results from this study will be combined with other MOSS studies to assist the outfall siting and design process and allow evaluation of potential impacts to the marine environment from secondary treated wastewater.

Characterization of Trace Metal Concentrations in Marine Waters of the Central Puget Sound Basin

Scott Mickelson, Melinda Brockington, Scott Carpenter *and* ***Thomas Georgianna***
King County Department of Natural Resources

Population growth in King County has necessitated planning a new wastewater treatment plant in northern King County or southern Snohomish County with a Puget Sound outfall. King County is conducting the marine outfall siting study (MOSS) to assist in the outfall siting and design process. A study of trace metal concentrations in central Puget Sound marine waters was undertaken as part of MOSS. This study characterizes existing conditions in Puget Sound and allows evaluation of potential impacts to the marine environment from secondary treated wastewater.

Marine water samples were collected monthly from April 1999 to May 2000 from three depths at eight sampling sites in Puget Sound. Sampling followed "clean hands/dirty hands" protocols and employed new, non-contaminating sampling gear. Samples were analyzed for 14 trace metals using analytical technologies that provided ultra-low level detection limits. Sample preparation employed a reductive co-precipitation technique to remove matrix interference and pre-concentrate the sample.

Preliminary statistical analysis of the data indicates that sampling has been sufficient to characterize the mean for each metal at every site and depth sampled. The data are symmetrically distributed and display small coefficients of variation which enables the use of a one-way ANOVA for testing differences among sites.

A Three-dimensional Water Quality Model of Southern Puget Sound

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A three-dimensional hydrodynamic and water quality model of southern Puget Sound was developed based on the EFDC model[1]. The water quality model simulates the concentration of dissolved oxygen (DO) in response to primary production of phytoplankton, oxidation of organic material, and sediment flux. Of the 21 possible state variables in EFDC, the model of southern Puget Sound includes: two phytoplankton groups, three forms of organic carbon, three forms of organic phosphorus and nitrogen, dissolved reactive phosphorus, ammonia nitrogen, nitrate plus nitrite nitrogen, chemical oxygen demand, and dissolved oxygen. Fecal coliform was also included.

A sediment process model is coupled with a water column model. The sediment model incorporates three processes: depositional flux of particulate organic matter (POM); diagenesis of POM; and the resulting sediment flux.

The model was calibrated to limited data collected between October 1996 and September 1997. Because of the relative scarcity of data, the model is only crudely calibrated at the present time. We will summarize the current state of the model application to southern Puget Sound, including results of the calibration to the existing data.

[1] Hamrick, J.M. 1994. Linking hydrodynamic and biogeochemical transport models for estuarine and coastal waters. Estuarine and Coastal Modeling. Proceedings of the 3rd International Conference. M.L. Spaulding et al Eds., American Society of Civil Engineers, NY, pp 591-608.

Characterization of Light Absorption by Particulate and Dissolved Substances Within Puget Sound

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Chlorophyll a, an indicator of phytoplankton biomass, exhibits large temporal and spatial variability within Puget Sound that is unresolved by most monitoring programs. The remote sensing of ocean spectral reflectance (color) provides a means to remotely assess surface chlorophyll concentrations and other water quality indicators which can complement existing monitoring efforts. The development of models relating ocean color to chlorophyll requires information on the relative contribution and variability of absorbing materials (e.g. chlorophyll, particulate detritus, dissolved materials) to the optical properties of Puget Sound waters. To address this question, we are measuring the spectral absorption characteristics of dissolved and particulate materials in water samples collected monthly as part of the Puget Sound Ambient Monitoring Program. We present seasonal trends in spectral absorption at various locations throughout Puget Sound, characterize the major light absorbing components and their relative contributions to seawater absorption, and describe their relationship with phytoplankton biomass.

Water Circulation and Fecal Coliform Budget of Dungeness Bay, Washington

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Fecal coliform concentrations have increased in portions of Dungeness Bay, resulting in commercial shellfish closures. Our study determined tidal circulation patterns, water and fecal coliform budgets. Sources of fecal coliform included the Dungeness River, harbor seals, seabirds, irrigation-ditches and

shoreline septic system leakage. We used boats equipped with simultaneous GPS/depth sounder/CTDs to map bathymetry, circulation and water quality. Fecal coliform samples were collected at the mouth of the bay to determine inflow and outflow rates. Samples were also collected along drifter pathways to map coliform distribution and contribution by sea birds or seals and to generate estimates of coliform dieoff.

The Dungeness River was determined to be a major source of fecal coliform to the bay during the flood tide but not during the ebb when river flow was toward the Strait of Juan de Fuca. Harbor seals and birds were also important contributors. Irrigation ditches that periodically discharge to the bay had relatively low flow and often very high fecal coliform concentrations. A low-lying residential beach community located east of the bay is the type of area where septic system failure is common. However, the prevailing circulation in this area flowed away from the bay entrance, minimizing its fecal coliform contribution to Dungeness Bay.